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ALTERING FATTY ACID COMPOSITION OF RUMINANT PRODUCTS BY ENCAPSULATION OF VEGETABLES FATS

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DIGESTION IN THE RUMINANT

The unique digestive system of the ruminant developed to enable this animal to utilize most efficiently the carbohydrate or cellulosic materials which are the main energetic components of plant feedstuffs. Table 1 shows relative advantages and disadvantages of digestion of feedstuffs in the rumen. The rumen, which may be likened to a large vat of micro-organisms, makes it possible for the ruminant to convert low quality feedstuffs, unsuitable for most monogastric animals, to meat and dairy products. The development of this unique digestive system also enables these animals, by grazing, to use productively marginal lands which cannot be used for intensive crop production.

The ruminant, however, does not use the other plant energy sources, protein and lipid, as efficiently. These constituents are broken down and used by the rumen microorganisms themselves for their own growth and metabolism. Thus, dietary protein is converted in the rumen to bacterial protein which then is digested in the intestinal tract to provide the protein needed by the animal. Similarly, extensive metabolism of lipids occurs in the rumen. The plant lipids of the ruminant diet contain very high proportions of polyunsaturated fatty acids. These polyenoic lipids are hydro-

Table 1. Advantages and disadvantages of digestion in the rumen

Dietary Component	Rumen Reactions	Advantages	Disadvantages
CARBOHYDRATE	VFA	Use of low quality non-competive plant foods	Use of some energy by microbes
		Digestion of cellulose by microbes-lack of cellulytic enzymes in mammals	
PROTEIN	AA		Conversion to protein of lower biological value
	NH_3 bacterial protein		
	CO_2		Use of some energy by microbes
	CH_4		
LIPID	Shorter chain FA		Loss of lipid of diet Formation of trans-FA
	VFA		
	unsatd FA satd FA		Ruminant milk and meat is satd - cardiac risk

lyzed in the rumen and converted by the microorganisms into more saturated fatty acids. Thus the nature of the dietary lipids is changed by rumen metabolism and saturated fats are absorbed in the intestine. Although polyunsaturated lipids are ingested by the ruminant, primarily saturated lipids appear in ruminant meat and milk.

Recognition of these differences in carbohydrate, protein, and fat metabolism in the rumen has led to attempts to manipulate the handling of these materials to maximize the efficiency of utilization. Obviously, it is desirable to continue to ferment cellulose in the rumen to produce volatile fatty acids, which are the animal's primary source of energy.

It is also apparent that lipid and protein utilization is not as efficient in the ruminant as in the monogastric animal. Therefore, it would be desirable to allow proteins and fats to by-pass the rumen, avoiding metabolism and utilization by the bacteria, thus entering the monogastric portion of the alimentary tract relatively intact so that they may be digested and absorbed more efficiently.

RUMINAL BY-PASS TECHNIQUES

Physiological Techniques

Two approaches have been utilized in recent years to accomplish this (Table 2). Use of the esophogeal groove reflex is a physiological technique which has generally been applicable only to young animals. This procedure has been studied extensively by Orskov and his associates (1,2). They investigated the young ruminant as it suckles and ingests liquids such as milk. It has the ability to close off access to the rumen and allow the ingested liquid to pass directly into the abomasum. Orskov found that young animals can be trained to utilize this erflex so that their feedstuffs are digested and absorbed as in the monogastric animal. There are obvious limits to this technique: the feedstuffs must be essentially liquid or in suspension to avoid fermentation in the rumen (2), and the ruminant's natural advantage of utilizing large quantities of low quality roughages

Table 2. Approaches to permit dietary components to by-pass the rumen

PHYSIOLOGICAL	1.	Esophogeal groove closure
	2.	Salt and water ratio
FOOD PROCESSING	1.	Alteration of physical form of the diet-reduce particle size
		A. Grinding
		B. Pelleting
	2.	Alteration of protein
		A. Heat
		B. Tannins
		C. Aldehydes acetaldehyde, acrolein butyraldehyde, formaldehyde glutaraldehyde, glyoxal propionaldehyde, trioxane
	3.	Encapsulation of lipids within a protein coating

might be impaired by retarded development of ruminating capacity.

Another physiological technique which has been studied is the use of high salt intakes to increase the rate of passage through the rumen (3).

Processing Feedstuffs

A second approach which has received great attention from agricultural scientists recently is the processing of feedstuffs so that they will withstand bacterial action in the rumen. Several techniques which have been used to prevent degradation in the rumen are:

1. *Alteration of the physical form of the diet*

Reducing the particle size of the roughage and concentrate feeds increases their rates of passage through the rumen. This provides a shorter exposure time to the microorganisms and results in a shorter fermentation period (4). Grinding and pelleting have been studied and used extensively.

2. *Thermal and chemical alteration of the protein of the diet*

a. *Heat.* Chalmers et al. (5,6) have demonstrated that heat treatment of casein rendered the protein less soluble, decreasing its breakdown in the rumen and increasing nitrogen utilization in sheep.

b. *Tannin.* Vegetable tannins have been used to treat peanut and soybean meal to make them less soluble in the rumen (7, 8, 9). Hydrogen bonds are formed between hydroxyl groups of the tannin and carboxyl groups of the peptide bonds of the protein. Dreidger and Hatfield (10) found that lambs fed tannin-treated soybean meal showed greater feed efficiency, gain, and nitrogen utilization.

c. *Aldehydes.* Ferguson and his coworkers (11) protected proteins by treatment with formaldehyde and found that they escaped breakdown in the rumen, were utilized more efficiently, and increased wool growth. In subsequent experiments, increased wool growth (12) and body weight gains (13) were observed. Peter and his coworkers (14) screened a series of aldehydes (acetaldehyde, acrolein, butyraldehyde, formaldehyde, glutaraldehyde, glyoxal, propionaldehyde and trioxane) to determine their effectiveness in preventing degradation of soybean meal protein. Formaldehyde and gloyoxal were subsequently used and found to significantly increase growth.

We have considered that a detailed discussion of processing techniques involving 1) alteration of particle size of dietary components and 2) heat, tannin, and aldehyde treatment of proteins, is beyond the scope of the present report. We have therefore limited the information in this report primarily to a description of our own work at Beltsville in which we have altered the fatty acid composition of ruminant products by encapsulation of vegetable fats.

3. *Encapsulation of lipids with a stable protein coating.*

Figure 1 compares schematically the normal process of digestion

which plant fat undergoes in the ruminant with the digestion of encapsulated lipids. In the neutral conditions of the rumen, microorganisms hydrolyze and hydrogenate the dietary glycerides, which are then absorbed as saturated fatty acids in the small intenstine. These microbial hydrogenation processes are responsible for the fact that meat and milk fat contain only 2–4% polyunsaturated fat, although the plant fat which ruminants usually ingest contains 60–70% polyunsaturated lipid.

Several years ago, scientists in Australia (15, 16) developed a technique in which vegetable oils were enclosed in a protein coat and then treated with formaldehyde. The cross-linking between formaldehyde

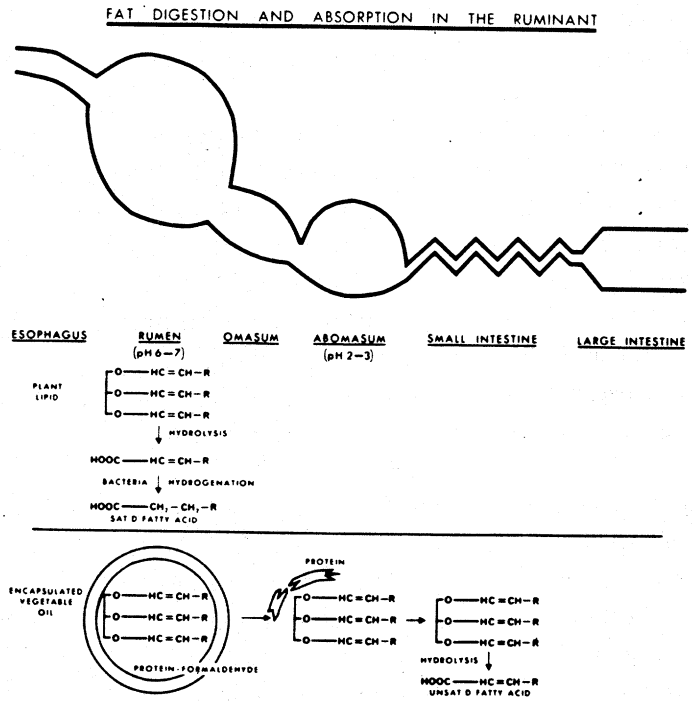

Fig. 1 Comparison of digestion and absorption of plant lipids and encapsulated vegetable oils in the ruminant.

and amino groups of the protein makes the coating relatively insoluble and inert to bacterial attack under the neutral (pH 6–7) conditions in the rumen. After passing into the abomasum, the formaldehyde-protein coat is disrupted by the more acidic conditions (pH 2–3), releasing the unchanged vegetable oil which can be digested and absorbed in the small intenstine as a polyunsaturated lipid.

Studies of risk factors associated with coronary heart disease have demonstrated that populations consuming diets high in saturated fats had high mortality rates (17, 18). Our research has been directed towards finding ways in which the saturated fat of milk can be replaced with polyunsaturated fat. Accordingly, we have encapsulated a variety of polyunsaturated vegetable oils and studied a number of encapsulation techniques in efforts to develop practical feed supplements.

PREPARATION OF LIPID FEED SUPPLEMENTS

In attempts to develop practical feed supplements, a number of variations in encapsulation methodology were studied and are shown in Table 3. All of the encapsulated lipid particles we have prepared contained approximately 1% formaldehyde.

Methods of Preparation

1. Spray-drying

Most of the early encapsulated lipid feeds (15, 16, 19, 20) were prepared by homogenizing a pure vegetable oil with a solution of sodium caseinate (about 10 percent casein heated to 70°C), treating with formalin (6 to 8 percent by weight of protein) and spray drying (Fig. 2). These preparations usually had an oil: casein ratio of 2:1. Both the pure vegetable oils and the casein are expensive starting materials and costs of production have been high.

One approach to reduce costs of production was to use cheaper raw

Table 3. Variations in encapsulation methodology

LIPIDS ENCAPSULATED	PROTEIN COATING MATERIALS	ENCAPSULATION TECHNOLOGY	CROSS-LINKING AGENTS
Pure Vegetable Oils	Casein	Spray-drying	Formaldehyde
Safflower	Whey	Flash-drying	Glutaraldehyde
Cottonseed	Gelatin	Coacervation	
Corn	Gum Arabic		
Soybean	Soybean		
Whole Oilseeds	Sunflower		
Sunflower seeds	Sesame		
Soybeans			
Sesame seeds			
Oilseed Products			
Full-fat soy flours			
Soybean Soapstock			
Miscellaneous			
Beef tallow			
Triundecanoin			

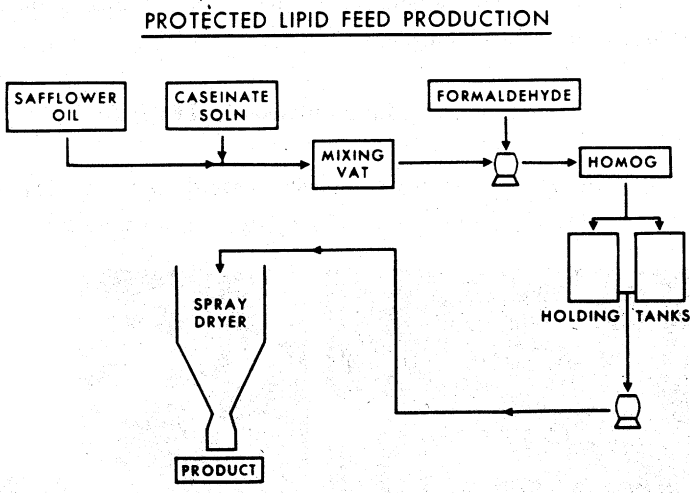

Fig. 2 Schematic representation of encapsulated lipid preparation by spray-drying.

materials. Homogenates of partially decorticated sunflower and safflower seeds (21) and full-fat soybean flours (22) have been treated with formaldehyde and spray-dried, thus avoiding the use of the more expensive starting materials.

2. Flash-drying

Several protected lipid feeds have been prepared by grinding whole seeds, treating with formaldehyde and flash-drying. A sunflower casein-formaldehyde feed has been prepared by this method (21. 23). A feed containing 70% sunflower seeds – 30% soybeans was also made by comminution in a hammer mill, passage through a colloid mill, formaldehyde treatment and flash-drying in a drum drier (24). Soybeans have also been ground, treated with formaldehyde and dried in air (25) or in forced air-ovens (20). Full-fat soy flours have also been treated with formaldehyde and air-dried (20, 26, 27).

3. Coacervation

We have prepared a feed supplement in our laboratory which consisted of safflower oil with a gum arabic-gelatin coating (28). Glutaraldehyde was used as the cross-linking agent.

Structure of Encapsulated Lipid Particles

Scanning electron micrographs (SEM) were used to evaluate particle sizes and differences among the encapsulated lipid materials (Fig. 3). The

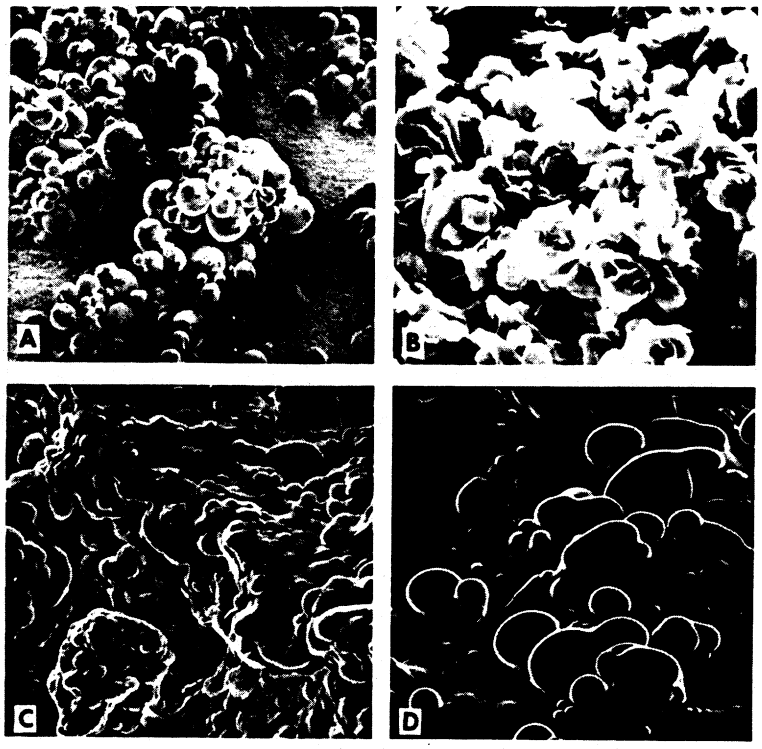

Fig. 3 Scanning electron micrographs (1000X) of particles of: (A) safflower oil-casein (2:1) formaldehyde; (B) formaldehyde treated, extrusion cooked, full fat flour; (C) formaldehyde treated sunflower-soybean (7:3); (D) formaldehyde treated tallow-soybean meal (4:6).

spray-dried safflower oil-casein-formaldehyde particles (A) appeared as discrete spheres (1-40μ in diameter). The formaldehyde treated, extrustion cooked, full fat soy flour particles are shown in Figure 3B. Numerous partially collapsed spheres are seen, ranging from 1-40μ in diameter. Loss of moisture from the interior of the particles during drying apparently led to a collapse of the skin that forms on the surface.

The sunflower-soybean-formaldehyde particles prepared by flash-drying are shown in the SEM of Figure 3C. Less discrete surface structures were present; larger protrusions or knobs, probably representing encapsulated lipid were seen, but there were few isolated spherical capsules. This is consistent with the fact that these particles were not prepared as homogenized microdroplets and sprayed through a small orifice, as were the capsules of Figures 3A and 3B.

The tallow-soybeam meal-formaldehyde particles are shown in the SEM of Figure 3D. The surface appeared to be a continuous fused coat with large amorphous protrusions. Little evidence of discrete spherical capsules was seen.

EFFECTS OF FEEDING ENCAPSULATED LIPIDS UPON MILK FAT POLYUNSATURATION

Table 4 presents a summary of some of the experiments we have conducted at Beltsville with encapsulated lipids. More detailed information concerning a specific oil or lipid preparation is contained in the research report noted in the reference column of the table. Since the C18 fatty acids in milk originate almost entirely from dietary sources, rather than from *in vivo* synthesis, they serve as excellent markers for the overall efficiency of the transfer process from the diet to the milk. Moreover, since polyunsaturated fats will only appear in milk to the extent that they pass through the rumen and avoid hydrogenation, the amount of 18:2 and 18:3 fatty acids in milk sefves as a fairly direct indicator of the effectiveness of the protective encapsulation process. Usually, 18:2 comprises only

Table 4. Effect of feeding encapsulated lipids upon milk fat polyunsaturation

Exp. No.	Lipid	Coating	X-ing	Dry Proc.	Duration of Exp.	Amt. Fed g/day	Percent 18:2 in Milk	Ref.
	Pure Vegetable Oils							
1	Safflower	casein	F	SD	5 days	1500	33	19
2	Safflower	casein	F	SD	35 days	200-2278	7-33	20
3	Safflower	casein	F	SD	16 weeks	800	13	29
4	Safflower	casein	F	SD	2.5 years	800	10	30
5	Safflower	gum-arabic gelatin	G	C-SD	5 days	800-1000	11-14	28
6	Soybean	casein	F	SD	14 days	400	6	31
7	Cottonseed	casein	F	SD	14 days	400	5	31
8	Corn	casein	F	SD	4 days	700	6	unpubl.
	Whole Oilseeds							
9	Soybean	nat. prot.	F	FD	3 days	3200	6	20
10	Sunflower	soybean nat. prot.	F	FD	35 days	524-8384	7-20	24
11	Sesame	nat. prot.	F	FD	7 days	1500	4	unpubl.
	Oilseed Products							
12	Full-fat soy flour	nat. prot.	F	FD	5 days	1900	4	20
13	Full-fat soy blakes	nat. prot.	F	FD	3 days	2000	4	20
14	Full-fat soy flour	nat. prot.	F	SD	2 days	1500	8	22
15	Full-fat soy flour	whey	F	SD	5 days	3100	8	28
16	Soybean soapstock	casein	F	FD	4 days	1600	3	unpubl.
	Miscellaneous							
17	Triundecanoin	casein	F	SD	4 days	800	incr. 11:0	32
18	Beef tallow	soybean	F	FD	18 weeks	2100	incr. 18:1	33

F=formaldehyde; G=glutaraldehyde; SD=spray-dried; FD=flash-dried; C=coacervation; nat. prot.=natural, native protein of oilseed; X-ing=cross linking

2 to 4% of the fatty acids of milk fat. Thus, increases to 6% or more are indicative of successful encapsulation of the polyunsaturated lipid, survival in the rumen, and transfer into milk fat.

In most of our experiments, we fed lactating Holstein cows a spray-dried safflower oil-casein-formaldehyde preparation (exps 1-5). A dose-response experiment (exp. 2) demonstrated that increases in polyunsaturation of milk fat up to 33% could be achieved when large amounts of the protected lipid were fed. We also prepared and tested protected feeds containing other pure vegetable oils, soybean, cottonseed and corn oil.

Reducing the cost of protected feeds is an important aspect of this research and crucial to its success. We have experimented with cheaper protected lipid supplements produced by using cheaper raw materials, the oilseeds themselves or processed products, and by using the natural, native protein of the plant material to encapsulate the lipid. A mixture of 70% sunflower seeds and 30% soybeans was found to be a practical feed to increase the polyunsaturation of milk fat (exp. 10). Another practical protected lipid supplement consisted of a formaldehyde treated, extrusion cooked full-fat soy flour (exp. 14). With this material we achieved high efficiencies of transfer of dietary 18:2 and 18:3 into milk fat.

The experiments involving sesame seeds (No. 11), full-fat soy flour and flakes (Nos. 12 & 14), and soybean soapstock (No.16), were unsuccessful in producing polyunsaturated milk. The 18:2 content of milk fat did not rise above 4%. They must be regarded either as 1) a failure to achieve encapsulation of 2) overprotection, where the protein was so highly crosslinked that it was not digested in the abomasum and the polyunsaturated oils were not released for absorption.

Also shown in Table 4 are two experiments in which we fed an encapsulated odd-numbered triglyceride, triundecanoin, and protected beef tallow, containing large amounts of 18:1 triglycerides. Both of these preparations had little influence on the percentage of 18:2 in milk, but the encapsulated C 11 triglyceride increased the amount of C 11:00 in milk and the protected tallow increased the 18:1 content of milk.

The changes that occur in the milk, blood and body tissues of cows consuming the protected polyunsaturated lipid feeds are very similar, irrespective of the particular vegetable fat used. A few specific examples will be given to illustrate several of these characteristic effects.

Milk Fat Yield

The plant diet of the dairy cow contains only small amounts of fat, usually ca 2.5 to 3.0 percent of total intake. The addition of the encapsulated lipid to the ration results in the transfer of greater amounts of

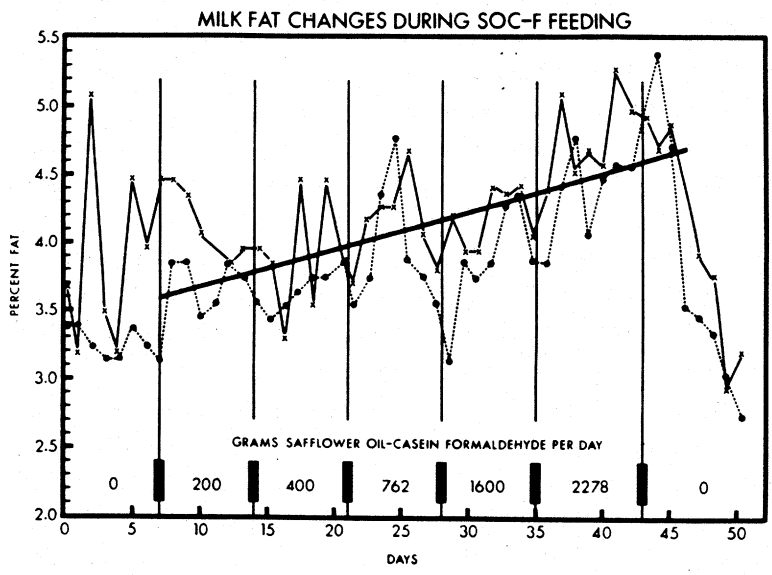

Fig. 4 Daily milk fat changes for two cows during safflower oil-casein formaldehyde feeding. Regression line gives the relationship between percent fat and intake of encapsulated lipid supplement.

fat into the milk. Figure 4 shows the increase which occurs in the percent fat content of milk as increasing amounts of protected safflower oil were fed: milk fat increased from 3.5 to 4.5 percent. The amount of the fat increase is, of course, dependent upon the amount of protected lipid fed, but an increase in milk fat yield has been a consistent and uniform finding.

Fatty Acid Composition of Milk Fat

When the composition of the fatty acids of milk fat was examined, a large increase in 18:2 content was observed as increasing amounts of the protected safflower oil were fed (Fig. 5). The 18:2 content was 3% at the beginning of the experiment and increased to 33% at the top level. There were small increases in 18:1 and 18:0 in the milk fat. The major acids showing a compensatory decline were palmitic, 16:0, which decreased from 35% to 14% and myristic, 14:0, which declined from 13% to 4% as the encapsulated safflower oil level increased.

Cholesterol Content of Milk, Blood and Body Fat

When a protected polyunsaturated vegetable oil is fed, blood cholesterol, triglycerides and nonesterified fatty acids all increase. Figure 6 shows the increase in blood cholesterol which occurs when protected safflower oil was fed for 4 months. The two-fold increase in cholesterol was interpreted to be an obligatory response to aid in transport of greater amounts of circulating 18:2 fatty acids and total lipids. In spite of the very large increase in blood cholesterol, there was no increase in cholesterol in the milk, indicating a blood-milk barrier for cholesterol.

Cholesterol concentrations in body fat and in meat were not increased by protected lipid feeding (34, 35). In spite of large increases in blood cholesterol, there were no significant increases in cholesterol concentration in liver, heart, chuck or round muscle (Fig. 7). It thus appears that transfer of cholesterol from the plasma pool to body tissue is limited.

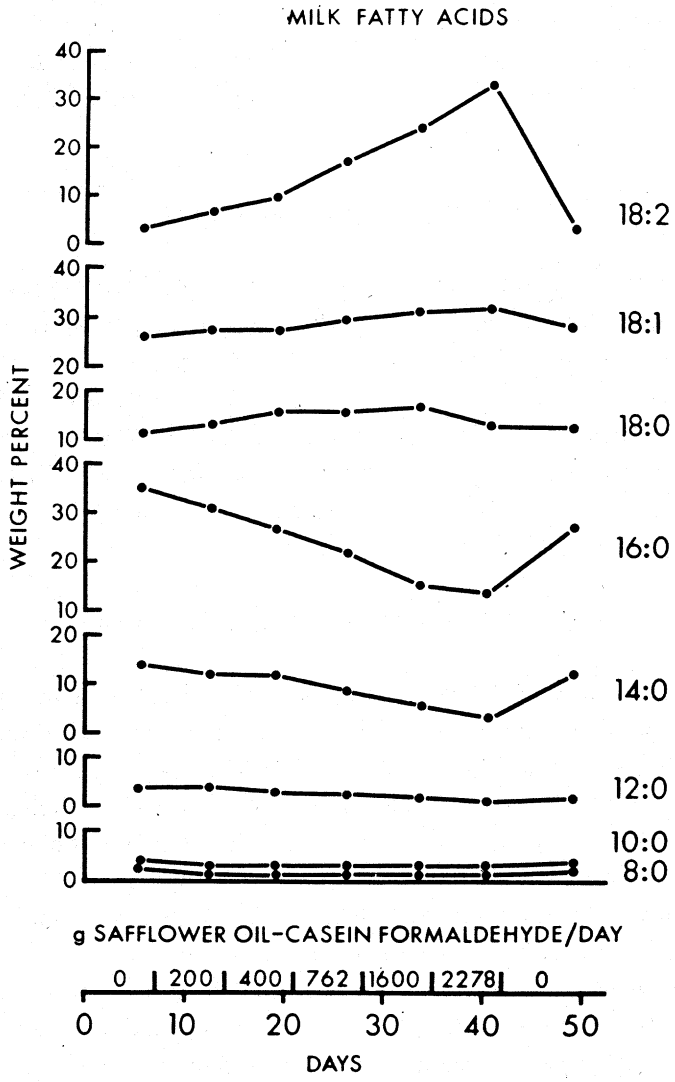

Fig. 5 Effect of increasing dietary safflower-oil-casein formaldehyde levels on milk fatty acids.

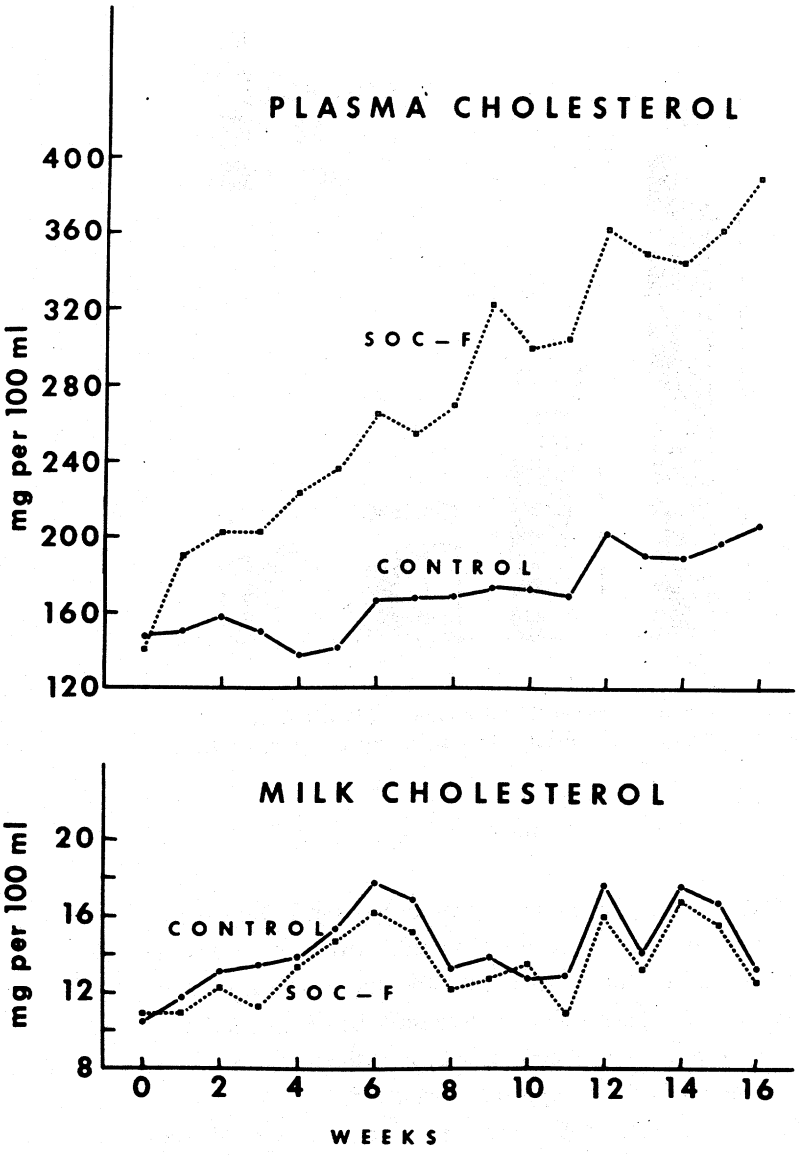

Fig. 6 Blood and milk cholesterol during safflower oil-casein formaldehyde feeding.

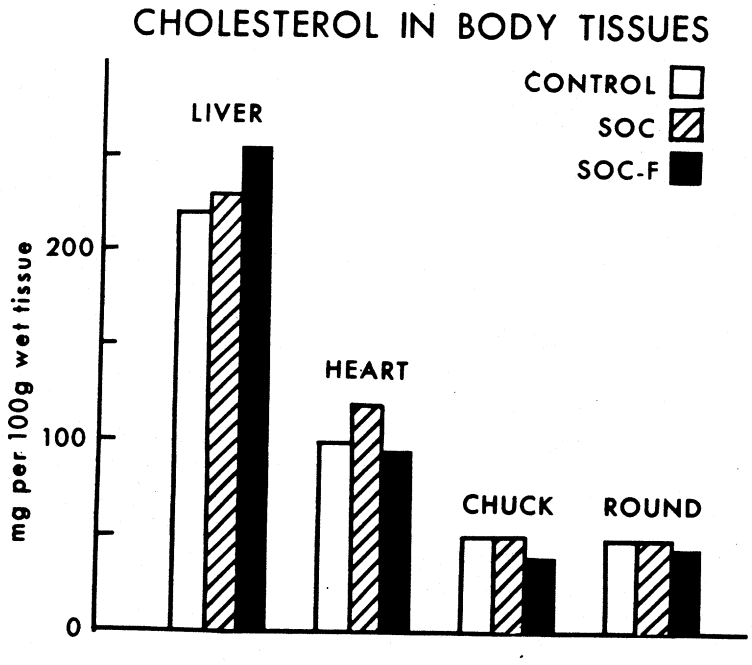

Fig. 7 Effect of feeding protected (SOC-F) and unprotected (SOC) safflower oil-casein on cholesterol concentration of tissues of cows.

Vitamin E

When we fed increasing amounts of a protected sunflower-soybean preparation to lactating dairy cows, we observed a two-fold increase in plasma vitamin E (Fig. 8). This increase could be due to a) the relatively high concentration of tocopherol in sunflower seed, b) the protection of vitamin E by the encapsulation procedure, and/or c) the increased fat uptake as increasing amounts of lipid supplement were fed.

In two other experiments we have observed increased vitamin E levels associated with protected lipid ingestion. When supplemental vitamin E was given to cows fed a control ration and to those fed protected safflower oil, vitamin E increased three-fold in the milk of the cows fed the encap-

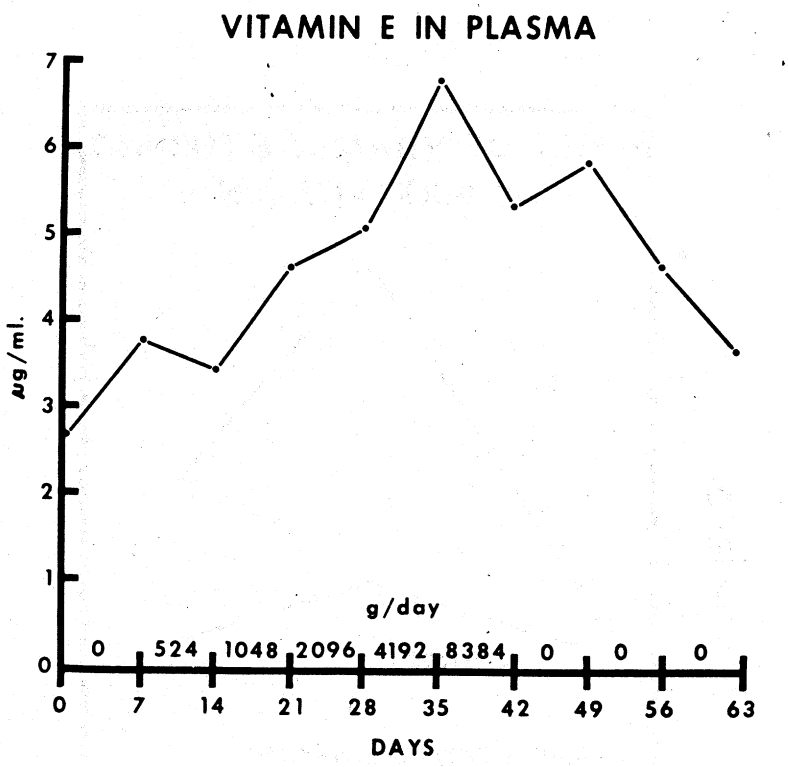

Fig. 8 Vitamin E in plasma of two cows fed formaldehyde treated sunflower-soybean (7:3) supplement.

sulated oil (Fig. 9). In another experiment, veal calves were raised on milk supplemented with tocopherol, then fed diets containing protected or unprotected safflower oil (36, 37). Tocopherol levels in the depot round fat of the experimental animals were 3 to 7 times the levels of commercial veal. These experiments all suggested that tocopherol uptake from the diet was enhanced by the encapsulation process.

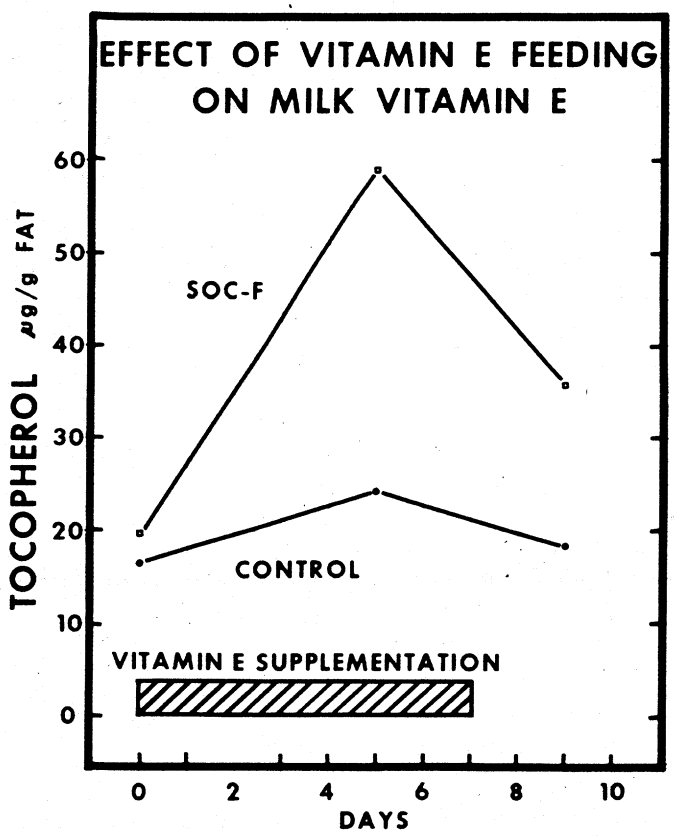

Fig. 9 Effect of vitamin E feeding on milk vitamin E levels of cows fed control or safflower oil-casein formaldehyde supplement diets.

Summary of Effects upon Milk, Blood and Body Fat

An outline of typical effects of feeding encapsulated polyunsaturated lipids to lactating dairy cows is presented in Table 5.

Table 5. Effects of feeding encapsulated polyunsaturated lipid

Compartment	Percent Fat	18:2	Satd. C_{4-16}	Vit E	Chol
Milk	+	+	–	+	0
Blood	+	+	–	+	+
Body Fat	+	+	–	+	0

HEALTH ASPECTS. FORMALDEHYDE

We have been concerned about the long-term effects of feeding formaldehyde protected polyunsaturated plant lipids to cattle. The consequences of continued exposure in terms of cow health, reproductive function, milk yield, blood and fat characteristics, blood and milk cholesterol, and possible cardiovascular sequelae have not been reported. Attention was also given to the possibility of formaldehyde residues in milk. While formaldehyde is a normal intermediate in the metabolic pathway for synthesis of methyl groups in the body, in high concentrations it is a toxic and poisonous substance. We investigated the possibility that some of the formaldehyde might a) exert effects upon the health of the animals, and b) accumulate in the milk and tissues of the animals. We therefore conducted a long-term experiment extending through two complete lactations over a period of two and one-half years to answer some of these questions (30).

We have found no adverse effects of feeding formaldehyde protected lipids to dairy cows. Clinical health remained good, and all cows conceived and calved normally. After about two and one-half years, the cows were slaughtered and hearts, aortas, and coronary arteries examined grossly for atherosclerotic lesions. Half of each aorta was stained with Sudan IV and sections were taken for histological study. The condition of the hearts

and major arteries was judged to be normal for cattle of this age. The histological preparations showed very little sudanophilia in either aortae or coronary arteries.

The amount of formaldehyde that we recovered from milk was extremely small. The formaldehyde determination procedure involves acid digestion and distillation and we have found that the procedure itself generates small quantities of formaldehyde. We have found no greater quantities of formaldehyde in milk from herd cows fed normal rations than in the milk from cows fed the formaldehyde treated encapsulated lipids (30). In a study designed to examine the metabolic fate of the formaldehyde of encapsulated safflower oil, Mills *et al.* (38) fed sheep and goats formaldehyde-treated casein-safflower oil particles containing ^{14}C-formaldehyde. They found no labeled formaldehyde in the body tissues and milk. The formaldehyde content of meat and milk from ruminants receiving their formaldehyde-treated diets was the same as that from animals on conventional diets.

RUMINANT PRODUCTS CONTAINING INCREASED AMOUNTS OF LINOLEIC ACID

Dairy Products

A wide variety of dairy products has been prepared from milk containing increased amounts of linoleic acid as a result of feeding encapsulated vegetable fats to dairy cows. In fatty acid composition, these products reflect the milk from which they are made, and generally, are characterized by large increases in 18:2, increases in 18:1 and 18:0, and decreases in saturated C 4-16 fatty acids. A listing of products that have been made is given in Table 6.

Research on the commercial development of polyunsaturated dairy products has proceeded intensively in Australia. These dairy products containing higher levels of linoleic acid are more susceptible to oxidation and development of off-flavors than conventional dairy products. Control

of this problem can be achieved by the addition of anti-oxidants. Moreover, when lipid supplements utilizing oil seeds are fed, the milk appears to be less liable to oxidation than when pure vegetable oil-casein supplements are used. A detailed review of the altered chemical and physical properties of the products, oxidative stability, and flavor are subjects not within the scope of this report and will not be presented.

Ruminant Meats. Beef, Veal, Lamb and Mutton

Feeding protected vegetable lipids will readily increase the polyunsaturation of the depot lipids in cattle and sheep (Table 6). Young steers (400-500 lbs) reach a maximum tissue 18:2 level after 8 weeks of feeding. When heavier steers were fed, only small increases in 18:2 were noted,

Table 6. Ruminant products containing increased amounts of linoleic acid

Product	% 18:2	References
A. DIARY		
Butter	3-33	39, 40, 41, 42, 43, 44, 45
Cheddar Cheese Processed Cheddar cheese	2-32	42, 46, 47, 48, 49
Cheedam, Gouda, Brie, Camembert, cream cheeses, Yogurt, sour cream	25	46, 47, 48, 49
Margarine	18-20	50
Milk	5-35	51, 52, 53, 54, 55
B. MEAT		
Beef	4-35	34, 49, 50, 56, 57, 58, 59, 60
Beal	9-13	36, 37
Lamb	11-20	49, 61, 62, 63, 64, 65, 66
Mutton	15-28	16, 50, 62

suggesting a slower turnover and deposition of lipid in these animals as compared to the more rapidly growing younger animals.

The protected lipids brought about similar increases in depot fat 18:2 in calves, and in lambs, where the deposition of dietary 18:2 appears to be particularly rapid. In contrast to the results with older steers, older sheep responded to dietary 18:2 with a rapid deposition in depot fat.

FUTURE DEVELOPMENTS

Research into the practical preparation of polyunsaturated lipid feeds for ruminants, and the use of the resulting polyunsaturated ruminant products in the human dietary, is still in the early stages of development. There have been a number of research reports but extensive clinical studies have not yet been conducted (49, 67, 68, 69).

It should be recognized that the use of protected fat feeding to produce polyunsaturated meat and milk is a specialized technique and probably cannot supply polyunsaturated food for a large segment of the population. It can serve a specialized need for persons who must reduce their intake of saturated fats for medical reasons.

It is possible that this technique could be used to encapsulate other fat-soluble substances (vitamins, drugs, steroids) and to increase the content of these materials in ruminant products. It is also possible that encapsulation of oil seeds will also encapsulate natural anti-oxidants present in the seeds and result in their transfer into the products.

Research directed towards providing foods with altered fat content and composition is an opportunity to serve the health needs of man. The importance of this type of research rests upon the health problem that stimulated it. Coronary heart disease is a leading cause of death; the best medical and nutritional advice recommends reduction in saturated fats in foods, as well as an overall reduction in the total amount of fat. While the ultimate commercial future of these products cannot be predicted, this method provides a possible means whereby traditional foods can be produced, consumed, and enjoyed by the public without jeopardy

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